Classification of Players Across the Australian Rules Football Participation Pathway Based on Physical Characteristics

Journal of Strength and Conditioning Research

Classification of players across the Australian Rules football participation pathway based on physical characteristics

--Manuscript Draft--

Manuscript Number:	JSCR-08-13295R2
Full Title:	Classification of players across the Australian Rules football participation pathway based on physical characteristics
Short Title:	Australian Football physical development
Article Type:	Original Research
Keywords:	talent identification; TEAM SPORT; classification modelling; physical fitness; sport development pathway
Corresponding Author:	Jade Haycraft, Ph.D. Victoria University Melbourne, Victoria AUSTRALIA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Victoria University
Corresponding Author's Secondary Institution:	
First Author:	Jade Haycraft, Ph.D.
First Author Secondary Information:	
Order of Authors:	Jade Haycraft, Ph.D.
	Stephanie Kovalchik
	David Pyne
	Sam Robertson
Order of Authors Secondary Information:	
Manuscript Region of Origin:	AUSTRALIA
Abstract:	This study investigated the utility of physical fitness and movement ability tests to differentiate and classify players into Australian Football League (AFL) participation pathway levels. Players (n = 293, age 10.9 – 19.1 years) completed the following tests; 5-m, 10-m and 20-m sprint, AFL planned agility, vertical jump (VJ), running vertical jump, 20-m Multi-Stage Fitness Test (MSFT), and Athletic Ability Assessment (AAA). A multivariate analysis of variance between AFL participation pathway levels was conducted, and a classification tree determined the extent to which players could be allocated to relevant levels. The magnitude of differences between physical fitness and movement ability were level dependent, with the largest standardized effects (ES) between Local U12, Local U14s, and older levels for most physical fitness tests (ES: -4.64 to 5.02), except the 5-m and 10-m sprint. The 20-m, 5-m, AFL agility, 20-m MSFT, overhead squat, and running VJ (right) contributed to the classification model, with 57% overall accuracy reported (43% under cross-validation). National U16 players were easiest to classify (87%), while National U18 were most difficult (0%). Physical fitness tests do not appear to differentiate between players following selection into AFL talent pathway levels. Other attributes (i.e., skill, psychological, and socio-cultural) should be prioritized over physical fitness and movement attributes by selectors/coaches when considering selection of talented players.
Response to Reviewers:	Reviewer Comments: Reviewer #1: The authors have done a good job at responding to comments. Well done!

	Reviewer #2: No additional comments We would like to thank the reviewers for their time and kind feedback regarding this study. It is much appreciated. Note from Senior Associate Editor Thank you to the Senior Associate Editor for highlighting these formatting oversights. The suggested changes have been made throughout the manuscript •Please add a section/sub-heading at the start of the Methods section "Experimental Approach to the Problem (see author guidelines). Other sub-headings also need to be added. oThe correct Methods subheadings have now been added to the manuscript (pages: 5-7). •Check that you have used US spelling throughout e.g. prioritized. oThe spelling has now been changed US throughout the manuscript. •Please add some more to the Practical Applications section. How can strength and conditioning practitioners use your results? oWe agree with the Senior Associate Editor and the following has now been added to the Practical Applications section (page: 15, lines: 352-356): “Furthermore, strength and conditioning practitioners may identify players that are under-performing in key physical fitness and/or movement abilities important for their competition level. This would provide more informed and individualized strength and conditioning programs for players at varying development stages within the same AFL participation pathway level.” •References need to be formatted to the JSCR submission guidelines. Pay particular attention to journal names. oApologies for this oversight. The references have now been changed to the correct format.

8th July, 2019

To the Editors,
Journal of Strength & Conditioning Research

Category: Original Research
Title of manuscript: Classification of players across the Australian Rules football participation pathway based on physical characteristics

Please find attached the abovementioned manuscript for submission to *Journal of Strength & Conditioning Research.*

This manuscript is original and not previously published in any form including on preprint servers, nor is it being considered elsewhere until a decision is made as to its acceptability by the JSCR Editorial Review Board.

The attached manuscript has been read and approved by all the listed co-authors below. All co-authors meet the requirements of co-authorship as specified in the Authorship Guidelines provided by the Journal of Strength & Conditioning Research. Funding and financial support was provided by the Australian Football League Research Board. The Australian Football League Research Board also provided access to their databases for analysis by the research team. The proposed manuscript does not concern any commercial product. The authors report no conflicts of interest with information reported within this study.

We look forward to a positive review of our paper. Should you require any further information relating to the methods used in the study please do not hesitate to contact the corresponding author.

Yours sincerely,

Dr Jade A.Z. Haycraft
Corresponding Author
Institute for Health and Sport (IHES),
Victoria University,
P.O. Box 14428,
Melbourne, Victoria, Australia 8001
Ph: +61399194204
Email: jade.haycraft@vu.edu.au

Dr. Stephanie Kovalchik
Institute for Health and Sport (IHES),
Victoria University, Melbourne, Victoria,
Australia

Professor David B. Pyne
Research Institute for Sport and Exercise
(UCRISE), University of Canberra,
Canberra, Australia

Associate Professor Sam Robertson
Institute for Health and Sport (IHES),
Victoria University, Melbourne, Victoria,
Australia

Classification of players across the Australian Rules football participation pathway based on physical characteristics

Original Investigation

Jade A.Z. Haycraft[a], Stephanie Kovalchik[a], David B. Pyne[b], Sam Robertson[a]

a) Institute for Health and Sport (IHES), Victoria University, Melbourne, Australia,
b) Research Institute for Sport and Exercise (UCRISE), University of Canberra, ACT, 2617, Australia

Corresponding author contact details:

Email: (Jade Haycraft) jade.haycraft@vu.edu.au

Institute for Health and Sport (IHES), Victoria University,

P.O. Box 14428, Melbourne, Victoria, Australia 8001

Phone: +61399194204

Preferred Running Head:

Australian Football physical development

Abstract word count: 213

Text-only word count: 4165

Number of figures: 5

Number of tables: 1

Classification of players across the Australian Rules football participation pathway based on physical characteristics

ABSTRACT

This study investigated the utility of physical fitness and movement ability tests to differentiate and classify players into Australian Football League (AFL) participation pathway levels. Players (n = 293, age 10.9 – 19.1 years) completed the following tests; 5-m, 10-m and 20-m sprint, AFL planned agility, vertical jump (VJ), running vertical jump, 20-m Multi-Stage Fitness Test (MSFT), and Athletic Ability Assessment (AAA). A multivariate analysis of variance between AFL participation pathway levels was conducted, and a classification tree determined the extent to which players could be allocated to relevant levels. The magnitude of differences between physical fitness and movement ability were level dependent, with the largest standardized effects (ES) between Local U12, Local U14s, and older levels for most physical fitness tests (ES: -4.64 to 5.02), except the 5-m and 10-m sprint. The 20-m, 5-m, AFL agility, 20-m MSFT, overhead squat, and running VJ (right) contributed to the classification model, with 57% overall accuracy reported (43% under cross-validation). National U16 players were easiest to classify (87%), while National U18 were most difficult (0%). Physical fitness tests do not appear to differentiate between players following selection into AFL talent pathway levels. Other attributes (i.e., skill, psychological, and socio-cultural) should be prioritized over physical fitness and movement attributes by selectors/coaches when considering selection of talented players.

Keywords: Talent identification, team sport, classification modelling, physical fitness, sport development pathway

INTRODUCTION

The Australian Football League (AFL) is a professional sport that implements a draft and salary cap system to facilitate equitable competition. On this basis, talent identification and development of players is multidimensional and requires consideration from both performance and economic perspectives (21). The current AFL participation pathway involves two streams; the local participation pathway and talent pathway. The local participation pathway consists of; school/clubs/community teams (5-18 years of age), and open age league/associations (>18 years), while talent pathways comprise a smaller cohort of talent identified junior players (9). Generally, player selection into the talent pathway is based on objective test outcomes such as physical fitness and skills testing, and subjective match performance assessments conducted by coaches and talent scouts (32, 33). Players may be selected into senior competitions from either the participation or talent pathways, with elite players primarily selected through the annual AFL National Draft (22). While the structure of the AFL participation pathway may provide clear local participation and talent pathways for players, no studies have assessed the differences in physical fitness profiles between multiple levels of the local participation and talent pathways. Understanding the physical differences between local and talent pathways is important for short-term player development as it allows the implementation of training plans that are specific to the physical capacities of players at each AFL participation pathway level. Additionally, short-term training plans may also be tailored to AFL participation pathway levels with the aim of building the physical foundations required for long-term player development.

Talent identification and development are multi-dimensional, encompassing aspects of physical fitness (21), tactical and technical skills (1), psychological characteristics (18), and socio-cultural influences (3, 6). However, traditional talent identification in professional sports is typically cross-sectional in nature, with selection of junior athletes based on current sport performances, physical fitness, and anthropometric characteristics (19). The predictability and usefulness of cross-sectional talent identification models is often poor because they usually involve player selection for short-term success in junior competition, not long-term player development (8, 19, 25). Combining pressure for short-term success within junior competition and the natural variability of performance and development of adolescent athletes can influence player likelihood of selection/deselection into talent pathways (19). As such, it is important to understand the long-term physical development pattern of players as they transition through the AFL participation pathway.

Match performance of adolescent players is influenced by their physical and anthropometric maturity; early maturing players are likely selected into the talent pathway given their perceived physical advantage, placing late maturing players at a selection disadvantage (27, 32, 36). The representative selection policies used by the AFL may have some limitations to athlete retention because they lack the flexibility to account for long-term athlete development (19, 25). However, valid research involving longitudinal tracking of athletes in relation to talent identification and elite athlete development is limited (10, 11). This shortcoming may be attributed to sacrificing long-term development objectives, in favor of short-term performance outcomes valued by junior coaches and clubs (19). Further, the development of players is typically non-linear with multiple factors influencing football performance (19, 25). As such, the use of non-linear analysis to classify players (as opposed to linear methods) may identify varying combinations of physical fitness attributes which contribute to a player's likelihood of selection into AFL talent pathways.

The annual AFL National Draft Combine physical testing battery forms part of the AFL's talent identification process and includes the following; 20-m sprint, vertical jump (VJ) variations, AFL planned agility run, and multi-stage fitness test (MSFT) (22, 23, 32). These tests have shown to be useful for tracking career progression, recruiting trends, and selecting players for specific positions (22). Substantial differences in 20-m sprint, VJ, and 20-m MSFT are evident between selected and non-selected players at state and national levels within the AFL talent pathway (27, 32, 36). Similar findings were reported between AFL drafted and junior state level players in 20-m sprint, AFL agility, VJ, and 20-m MSFT (22, 23). Additionally, the Athletic Abilities Assessment (AAA) has been used to assess functional movement skills of players with the purpose of classification into talent pathway or senior elite levels, with higher level players performing better in the AAA compare to lower level players (15, 29-31). Furthermore, the AAA has shown moderate-to-large effects between elite AFL starters and non-starters, with starters achieving higher overall tests scores than non-starters (12). However, discrepancies exist between studies reporting the capacity of physical fitness and movement tests to differentiate players across the AFL participation pathway; only the 20-m sprint, VJ, and 20-m MSFT measures reported for Local U10 to U14 levels (13, 14, 16). Understanding how players' physical fitness and movement fluctuates across the entire AFL participation pathway levels may allow more informed decision-making by coaches/selectors on short- and long-term player selection and development priorities.

The primary aim of this study was to establish physical fitness and movement ability profiles of developing players at each level of the AFL participation pathway. A secondary aim was to determine the extent to which these profiles could be used to classify players into their corresponding pathway level. Additionally, we sought to establish whether specific physical fitness and movement ability tests were more accurate at identifying players within a given AFL participation pathway level than physical fitness and movement ability tests.

METHODS

Experimental Approach to the Problem

The AFL Draft Combine test battery is used nationally to assess the physical fitness characteristics of players, with AAA score previously reported used to differentiate between higher and lower level players (12, 15, 29-31). This study was a cross-sectional analysis of the male AFL participation pathway between 2016 and 2018 seasons, with each player assessed at one physical fitness testing session.

Subjects

All players (n = 293, age range: 10.9 – 19.1 years) were recruited from teams across multiple competitions and age groups within the AFL participation pathway. Seven AFL participation pathway levels were identified for analysis (Figure 1); four local participation pathway levels (Local U12, Local U14, Local U16, and Local U18), and three talent pathway levels (National U16, State U18, National U18). Local participation pathway players were classified as those participating in local, private school, or school sport academy competitions. Players were further classified into the following groups based on their age; Local U12 (n = 50, age range: 10.9 – 12.9 years), Local U14 (n = 94, age range: 13.0 – 14.8 years), Local U16 (n = 29, age range: 15.0 – 16.9 years), and Local U18 (n = 15, age range: 17.0 – 18.2 years) with age limits determined by age grouping policies stipulated by the AFL (5). For example, players were categorized by age based on the calendar year (January 1st to December 31st) of that competition year (e.g., Local U12 player ≤12 years on January 1st). Players competing in talent pathway levels during the testing year were classified as National U16 (n = 45, age range: 15.4 – 16.3 years), State U18 (n = 38, age range: 16.4 – 19.1 years), and National U18 (n = 22, age range: 15.9 – 16.7 years) according to the age level they competed. All players were recruited from the same state, apart from players within the National U18 team who are selected from regions across Australia. Ethical approval was obtained from the Victoria University Human Research Ethics Committee, with informed consent provided by participants or their parent/guardian prior to participating in this research.

*****Insert Figure 1 near here*****

Procedures

Physical fitness testing of players across the AFL participation pathway was conducted between September 2016 and April 2018. Physical tests were: 5-m, 10-m, and 20-m sprint (s), VJ and running VJ (left and right) (cm), AFL planned agility test (s), 20-m MSFT (level achieved), and the AAA (score), with all testing completed according to the standardized AFL Draft Combine protocols outlined in Woods, Raynor, Bruce, McDonald and Collier (32). Following the 2017 AFL season, the YOYO Intermittent Recovery (IR) 2 test replaced the 20-m MSFT test in the official AFL Draft Combine testing battery. The YOYO IR1, IR2, and 20-m MSFT are highly correlated (ICC: 0.81 – 0.95, $p \leq 0.01$), as such the 20-m MSFT was considered an appropriate surrogate measure of aerobic fitness and comparability to previous research findings (24). The AAA protocol consisted of the following movements performed in this specific order; overhead squat, lunge (left and right), push-up, chin-up, and single-leg Romanian Deadlift (RDL) (left and right) (30). Physical testing sessions followed a 10 min standardized warm-up inclusive of aerobic and dynamic activities (32). Anthropometric data including height (m) and body mass (kg) were collected prior to testing, with the order of physical fitness tests randomized within each group. The one exception to this condition related to the 20-m MSFT, which in line with AFL Draft Combine testing protocols, was completed last (23, 32).

Statistical analysis

Descriptive statistics were obtained for each of the 11 tests across the seven pathway levels. To determine the extent to which test scores differed between each level, a multivariate analysis of variance (MANOVA) was undertaken. All assumptions of the MANOVA were required to be met for players to be included in this analysis, with players only included if they were tested on all physical fitness and AAA movements (n = 154). Critical p-value for consideration of differences was reduced to 0.005 via the Bonferonni correction given multiple comparisons. Post-hoc comparisons between ability levels were undertaken using a Games-Howell test, given that nine of the eleven tests failed the Levene's test of equality of variances. Cohen's effect sizes (d) were also obtained for each comparison, with ≥0.2 described as trivial, ≥0.5 as moderate, and ≥0.8 as large effects (4). The descriptive statistics and MANOVA were undertaken using the IMB SPSS Statistics software V25 (Version 25.0, IBM Corporation, USA).

To determine the extent to which players could be classified into their respective ability level (n = 293), a classification tree was constructed using the IBM SPSS Statistics software V25 (Version 25.0, IBM Corporation, USA). To minimize overfitting, the minimum number of cases in order for a node to develop was set to 10, while the maximum tree depth was set to 10. A confusion matrix was outputted to determine the extent to which players from each level were classified accurately. Ten-fold cross validation was undertaken, with overall classification accuracy outputted for both training and cross-validated sets. Figures 2, 3, and Supplementary Figure 1 were produced using the *ggplot2* package within the RStudio® statistical computing software version 1.1.453 (RStudio, Boston, Massachusetts).

RESULTS

Physical Fitness Testing

Descriptive statistics and standardized differences in players' physical fitness tests and movement ability are presented in Figures 2, 3, and 4. A gradual increase in physical fitness for most tests occurs with each progression in local pathway levels (Local U12 to Local U18), with test performance remaining homogenous across talent pathway levels (National U16 to National U18) (Figure 2). Movement abilities were similar across all AFL participation levels for all AAA exercises. The one exception of the State U18 players scoring higher on the overhead squat and left lunge (Figure 3).

Comparison between AFL participation pathway levels indicated that the magnitude of the difference between physical fitness and movement ability was level-dependent. For example, smaller differences were evident between National U18 and State U18 (ES: -1.43 to 0.68), compared to National U18 and Local U12 (ES: -4.24 to 4.23) (Figure 4). However, no substantial differences between Local U12 and Local U14 for any physical fitness or movement ability test were observed. The 20-m sprint was the only test that exhibited substantial differences between Local U12 and Local U14s and all other AFL participation pathway levels (ES: -4.24 to -1.91). No difference was evident for 5-m sprint time between the Local U12 and Local U14s when compared to the other AFL participation levels, except for the Local U14 and National U18s (ES: -1.21). The Local U12s were slower compared to the National U18s for 10-m sprint time (ES: -2.45), with no differences observed for any other level. Local U14s showed slower 10-m sprint times compared to all other AFL participation levels except the Local U16 (ES: -1.89 to -1.44).

The Local U12s showed large differences from all AFL participation pathway levels for the AFL agility, VJ, running VJ (left and right), and 20-m MSFT (ES: -4.64 to 5.02) (Figure 4).

However, no differences were observed between Local U12 and Local U18s for the AFL agility and running VJ (left), or Local U16s for 20-m MSFT. The Local U14 showed no differences compared to other participation pathway levels (i.e., Local U12, Local U16, and Local U18) for AFL agility, VJ, running VJ, or 20-m MSFT. However, compared to the talent pathway levels (i.e., National U16, State U18, and National U18) the Local U14s test performance was lower for these physical fitness tests (ES: -2.66 to 3.17).

*****Insert Figure 2 near here*****

Athletic Ability Assessment

The MANOVA comparison of movement ability between AFL participation pathway levels indicated that the State U18 level had higher squat scores than the Local U12, Local U14, and National U16 (ES: 1.24 to 2.07) (Figure 4). State U18s also displayed higher lunge scores (right) compared to Local U12 and Local U14 (ES: 1.33 to 2.18). These players also displayed higher left lunge scores than Local U12, Local U14, Local U18, and National U16 levels (ES: 1.11 to 2.60). National U16 also showed higher left lunge scores compared to Local U14 players (ES: 0.80). Lower push-up and chin-up scores were observed between the Local U12 and Local U14s when compared to the State U18s, and State U18 and National U18s (ES: 1.38 to 2.38), with Local U14 also having lower chin-up scores (ES: 1.40) than National U16. Local U14s also had lower single-leg RDL scores (right and left) compared to the National U16 and State U18 levels (ES: 0.98 to 1.28).

*****Insert Figure 3 near here*****

*****Insert Figure 4 near here*****

Classification of Players by Fitness and Movement Ability

The utility of the fitness test scores and AAA measures to classify players into respective age groups and levels is shown in Supplementary Figure 1. It appears that 20-m, 5-m, AFL agility, 20-m MSFT, overhead squat, and running VJ (right) were the only tests identified within the classification model. For example, Local U12 and U14 were mostly identified as having 20-m sprint >3.31 sec, 20-m MSFT >9.2 shuttles, and AFL agility >9.82 sec. The National U16 and State U18 were mostly classified if they had: 20-m sprint <3.31 sec, 5-m sprint >1.07 sec, overhead squat score <6.5, AFL agility <9.19 sec. The State U18 and National U16 were differentiated by running VJ (right), with more State U18 classified with a jump height >66.5 cm, and more National U16 classified with a jump height <66.5 cm. The confusion matrix output derived from the training model is shown in Table 1. An overall classification accuracy of 57% was derived. The National U16 level players were most accurately classified based on the 11 tests (87%), whereas National U18 were the most difficult to classify (0%). A reduction in model performance was evident under 10-fold cross-validation, with overall classification accuracy reduced to 43%.

*****Insert Supplementary Figure 1 link near here*****

*****Insert Table 1 near here*****

DISCUSSION

Physical fitness and movement profile(s) gradually improved with each progression in competition level within the local participation level, however no change was observed between talent pathway levels (i.e., National U16, State U18, and National U18). Movement ability of players across the entire AFL participation pathway remained homogenous, with the exception of higher overhead squat and left lunge scores for the State U18s. The only physical fitness and movement ability tests that contributed to the classification model were the 20-m, 5-m, AFL agility, 20-m MSFT, overhead squat, and running VJ (right). Furthermore, the model accurately classified over half of the players into the correct AFL participation pathway levels based on these physical fitness and movement ability tests. The National U16 players were the easiest to classify, however no National U18 players were correctly classified based on these tests. Once players enter the National U16s level of the talent pathway, physical fitness and movement ability became less important in classifying players.

The largest within-level physical fitness tests performance variation was in the Local U12 and U14 levels, with these levels different to most of the AFL participation levels on all tests. Players within the Local U12 and Local U14s are not exposed to structured physical training at the recommendation of the AFL match policy guidelines (5). Consequently, the larger variation in performance within the Local U12 and U14s may be attributed to substantial between-subject variations in biological maturity of players within this group. Comparisons between physical fitness test performances and the Tanner stages of maturity in adolescent male athletes indicates that the Tanner 5 stage of maturity occurs at 14.4 ± 0.9 years, with Tanner 1 occurring at 11.4 ± 0.4 years and Tanner 2 at 11.9 ± 0.7 years (17). In junior soccer (U13-U16s) the biological maturity of players was positively correlated with jump, sprint, agility, and aerobic endurance performance across similar tests used in this study (20, 26). This effect may explain the expected physical fitness and movement differences between the Local U12, Local U14 and the older levels within the AFL participation pathway, as the younger players may be in the early stages of physical development.

Given almost half of the players were not able to be accurately classified based solely on physical fitness and movement ability, it appears that other factors are important in successful junior football. This is not surprising, given it is well established that successful elite players overcome a variety of organismic, environmental and task constraints (7, 25, 26). Organismic constraints such as growth, maturity, and learning stages all influence a player's physical fitness characteristics (7, 28). Environmental constraints include differences in game play, skill level, game rules, and field sizes (7, 25). Task constraints are the game objectives, sporting actions, and the physical fitness qualities needed for high-level match performance (7, 25, 26). As such, the inclusion of skills testing (i.e., kicking and handball tests), and performance measures such as decision making ability and match performance indicators (i.e., game statistics and match activity profiles) may improve the accuracy of the model (8, 26). Once selected into the AFL talent pathway, players' physical fitness characteristics and movement ability becomes more homogenous, as the classification model identified the National U18s as the most difficult to level to classify. The limited ability to differentiate players between older levels of the AFL talent pathway may result from other factors such as skill level; whereas younger and less skilled players may rely more on their physical fitness attributes in training and matches. Analysis of skills between State U18 and Local U18 AFL players indicated the State-level U18 players had greater skill execution (accuracy) in dominant and non-dominant kicking and handballing tests (33). Furthermore, a review of physical maturity and soccer skills from a relatively homogenous group of junior players indicated more biologically mature players expressed higher skill levels that may have resulted in more hours of practice experience (20). As such, as players transition through the AFL local participation and talent pathways other factors such as skills, psychological, and sociocultural influences may affect their selection into higher talent competitions (1, 18), more so than physical fitness and movement ability.

The exclusion of physical fitness and movement tests from the classification model (i.e., 10-m sprint, VJ, left running VJ, and AAA tests) suggests the limited importance these tests have in AFL talent identification. This outcome supports previous assertions that VJ does not clearly relate to elite career progression in National U18 players, or contribute markedly to a player's chance of selection into higher levels of competition within the talent pathway (22, 23). Similarly, movement assessments appear limited for talent identification within the AFL participation pathway, as only the overhead squat score was included in the classification tree. These results contradict previous reports which indicate AAA has moderate discriminant validity between selected and non-selected State U18 players, as well as starters and non-starters in elite AFL players. Specifically, overhead squat, lunge, and single-leg Romanian deadlift (left) showed significant differences between selected and non-selected players (34, 35). The movements that form the AAA screening are considered foundational movements that underpin sport-specific movements such as: lower body and trunk stability, and triple extension patterns of the hip, knee, and ankle required from sprinting, jumping and change of direction (30, 31). Unsurprisingly, the Local U12 and U14s performed lower on the AAA screening which may be indicative of training restrictions imposed by the AFL match policy; a policy that provides recommendations on training foci for local participation pathway levels that include minimal-to-no focus on physical fitness training (i.e., strength and conditioning) (5). Conversely, the talent pathway levels are provided with physical fitness training, which creates a training age gap between local participation and talent pathway players (2, 7). Therefore, the outcomes of this study quantify the gap in movement abilities between the local and talent pathways, providing strength and conditioning practitioners within the talent pathway a baseline for incorporating short-term programs that target foundational athletic movement skills (12). Furthermore, differences in movement ability between elite and talent pathway players in previous studies highlight the importance of developing movement ability for long-term success (15, 29, 30). While the AAA screening may not contribute directly to the classification of players in this study, the movement ability of players may be an underpinning factor that influences of other performance factors such as technical skills (i.e., kicking and tackling), and match activity profiles.

The classification model included AFL agility which contradicts earlier reports. The extent to which the AFL agility test can clearly discriminate between AFL drafted and non-drafted players', or between talent pathway levels has been reported as questionable (22). However, AFL agility time was included in the classification tree and therefore may be useful for selecting Local level players into the talent pathway but not for selection into elite competition. Furthermore, the inclusion of the 20-m MSFT in this model also supports running endurance tests for differentiating between playing standards and career progression in State U18 and National U18 players (36). Linear analysis approaches may be constrained by a single function, and therefore may not be able to adequately identify differing physical fitness and movement ability patterns across multiple AFL participation pathway levels (23). A limitation of this study was that some groups only had a small number of players as they did not meet all the assumptions of the MANOVA analysis. Further work is required to consolidate these findings with larger samples to clarify the relationships between physical fitness and movement ability of players within the AFL pathways. However, non-linear approaches provide greater insight for coaches and talent selectors as they account for the patterns of physical fitness and movement ability differences across the AFL participation pathway.

This study characterized the physical fitness and movement profile(s) of developing players, the extent in which they differ between AFL participation pathway levels, and the degree to which they could classify players into specific pathway levels. All physical fitness and movement ability tests were strongest at differentiating Local U12 and Local U14 from all AFL participation pathway levels; however, differences were smaller for movement ability tests than physical fitness tests. The classification model indicated the 20-m and 5-m sprint, AFL agility, 20-m MSFT, squat, and running VJ (right) produced the highest accuracy in classifying players. National U16s were more accurately classified based on physical attributes, with the National U18 least accurate. The inability of physical fitness and movement ability tests to classify National U18 players highlights the need to seek more contextual information when selecting players into this level. As such, a limitation of this study is the restriction of this classification model to physical fitness and movement ability only. It is suggested future research should investigate models that incorporate skill measures, psychological, and sociocultural influences. Additionally, talent scouts and coaches should consider a combination of physical fitness and movement ability with other skill, psychological and sociocultural factors when selecting individual players into the AFL talent pathway.

PRACTICAL APPLICATIONS

Classifying players to specific AFL participation pathway levels using physical fitness and movement ability scores allows coaches and talent selectors to identify over-performing or under-performing players at a given level, thus highlighting players that may require further investigation of other contextual information. For example, a 15-year-old who concurrently competes in basketball and AFL may exhibit similar 5-m, AFL agility, and jump scores compared to an 18-year-old that has specialized early in AFL. This 15-year-old and/or 18-year-old could be flagged by talent selectors and coaches to investigate the players' sporting backgrounds as they present with physical fitness and movement abilities that are above/below their age level. Furthermore, strength and conditioning practitioners may identify players that are under-performing in key physical fitness and/or movement abilities important for their competition level. This would provide more informed and individualized strength and conditioning programs for players at varying development stages within the same AFL participation pathway level.

ACKNOWLEDGMENTS

The authors report no conflicts of interest with information reported within this study. All authors met the requirements for authorship in this journal and provided significant contributions to this article.

The authors thank all the teams and club managers who participated in testing days and arranged access to teams on game day. The authors thank the Australian Football League Research Board for funding this project.

This work was supported by the Australian Football League Research Board.

REFERENCES

1. Baker J, Côté J, and Abernethy B. Sport-specific practice and the development of expert decision-making in team ball sports. *J Appl Sport Psych* 15: 12-25, 2003.
2. Burgess D and Naughton G. Talent development in adolescent team sports: a review. *Int J Sports Physiol* 5: 103-116, 2010.
3. Burke M and Woolcock G. The impacts of transport accessibility and remoteness on Australian Football League (AFL) talent production: findings from the 'Talent Tracker' project. Presented at Australasian Transport Research Forum (ATRF), 35th, 2012, Perth, Western Australia, Australia, 2012.4. Cohen J. Statistical power analysis for the behavioral sciences. 2nd. Hillsdale, NJ: erlbaum, 1988.
5. AFL Community, Australian football match policy. 2008 http://www.aflcommunityclub.com.au/index.php?id=32. Accessed 9th May, 2018.
6. Côté J. The influence of the family in the development of talent in sport. *Sport Psychologist* 13: 395, 1999.
7. Davids K, Araújo D, Hristovski R, Passos P, and Chow JY. Ecological dynamics and motor learning design in sport, in: *Skill Acquisition in Sport: Research, Theory and Practice*. NJ Hodges, AM Williams, eds. New York: Routledge, 2012, pp 112-130.
8. Davids K, Araújo D, Vilar L, Renshaw I, and Pinder R. An ecological dynamics approach to skill acquisition: implications for development of talent in sport. *Talent Dev Excellence* 5: 21-34, 2013.
9. AFL Development. Participation and talent pathways. 2016. http://www.aflcommunityclub.com.au/index.php?id=26. Accessed 10 May, 2016.

10. Elferink-Gemser MT, Visscher C, Lemmink KA, and Mulder T. Multidimensional performance characteristics and standard of performance in talented youth field hockey players: a longitudinal study. *J Sports Sci* 25: 481-489, 2007.

11. Falk B, Lidor R, Lander Y, and Lang B. Talent identification and early development of elite water-polo players: a 2-year follow-up study. *J Sports Sci* 22: 347-355, 2004.

12. Garrett JM, McKeown I, Burgess DJ, Woods CT, and Eston RG. A preliminary investigation into the discriminant and ecological validity of the athletic ability assessment in elite Australian rules football. *Int J Sports Sci Coach* 13: 679-686, 2018.

13. Gastin PB, Bennett G, and Cook J. Biological maturity influences running performance in junior Australian football. *J Sci Med Sport* 16: 140-145, 2013.

14. Gastin PB, Tangalos C, Torres L, and Robertson S. Match running performance and skill execution improves with age but not the number of disposals in young Australian footballers. *J Sports Sci* 35: 2397-2404, 2017.

15. Gaudion SL, Kenji D, Wade S, Harry BG, and Carl WT. Identifying the physical fitness, anthropometric and athletic movement qualities discriminant of developmental level in elite junior Australian football: Implications for the development of talent. *J Strength Cond Res* 31: 1830-1839, 2017.

16. Haycraft JAZ, Kovalchik S, Pyne DB, and Robertson S. Physical characteristics of players within the Australian Football League participation pathways: a systematic review. *Sports Med Open* 3: 46, 2017.

17. Jones MA, Hitchen PJ, and Stratton G. The importance of considering biological maturity when assessing physical fitness measures in girls and boys aged 10 to 16 years. *Ann Hum Bio* 27: 57-65, 2000.

18. MacNamara Á, Button A, and Collins D. The role of psychological characteristics in facilitating the pathway to elite performance part 2: Examining environmental and stage-related differences in skills and behaviors. *Sport Psychologist* 24: 74-96, 2010.

19. Martindale RJJ, Collins D, and Daubney J. Talent development: A guide for practice and research within sport. *Quest* 57: 353-375, 2005.

20. Meylan C, Cronin J, Oliver J, and Hughes M. Talent identification in soccer: The role of maturity status on physical, physiological and technical characteristics. *Int J Sports Sci Coach* 5: 571-592, 2010.

21. Pearson D, Naughton GA, and Torode M. Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. *J Sci Med Sport* 9: 277-287, 2006.

22. Pyne DB, Gardner AS, Sheehan K, and Hopkins WG. Fitness testing and career progression in AFL football. *J Sci Med Sport* 8: 321-332, 2005.

23. Robertson S, Woods C, and Gastin P. Predicting higher selection in elite junior Australian Rules football: The influence of physical performance and anthropometric attributes. *J Sci Med Sport* 18: 601-606, 2015.

24. Thomas A, Dawson B, and Goodman C. The Yo-Yo Test: Reliability and Association With a 20-m Shuttle Run and VO2max. *Int J Sports Physiol* 1: 137-149, 2006.

25. Vaeyens R, Lenoir M, Williams AM, and Philippaerts RM. Talent identification and development programmes in sport. *Sports Med* 38: 703-714, 2008.

26. Vaeyens R, Malina RM, Janssens M, Van Renterghem B, Bourgois J, Vrijens J, and Philippaerts RM. A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *Br J Sports Med* 40: 928-934, 2006.

27. Veale J, Pearce AJ, Koehn S, and Carlson JS. Performance and anthropometric characteristics of prospective elite junior Australian footballers: A case study in one junior team. *J Sci Med Sport* 11: 227-230, 2008.

28. Wattie N, Schorer J, and Baker J. The relative age effect in sport: A developmental systems model. *Sports Med* 45: 83-94, 2015.

29. Woods C, Banyard HG, McKeown I, Fransen J, and Robertson S. Discriminating talent identified junior Australian footballers using a fundamental gross athletic movement assessment. *J Sports Sci Med* 15: 548-553, 2016.

30. Woods C, McKeown I, Haff GG, and Robertson S. Comparison of athletic movement between elite junior and senior Australian football players. *J Sports Sci* 34: 1260-1265, 2015.

31. Woods C, McKeown I, Keogh J, and Robertson S. The association between fundamental athletic movements and physical fitness in elite junior Australian footballers. *J Sports Sci* 36: 1-6, 2017.

32. Woods C, Raynor AJ, Bruce L, McDonald Z, and Collier N. Predicting playing status in junior Australian football using physical and anthropometric parameters. *J Sci Med Sport* 18: 225-229, 2015.

33. Woods C, Raynor JA, Bruce L, and McDonald Z. The use of skill tests to predict status in junior Australian football. *J Sports Sci* 33: 1132-1140, 2015.

34. Woods CT, Banyard HG, McKeown I, Fransen J, and Robertson S. Discriminating talent identified junior Australian footballers using a fundamental gross athletic movement assessment. *J Sports Sci Med* 15: 548, 2016.

35. Woods CT, McKeown I, Haff GG, and Robertson S. Comparison of athletic movement between elite junior and senior Australian football players. *J Sports Sci* 34: 1-6, 2015.

36. Young WB and Pryor L. Relationship between pre-season anthropometric and fitness measures and indicators of playing performance in elite junior Australian Rules football. *J Sci Med Sport* 10: 110-118, 2007.

Table 1. Confusion matrix for the classification-tree model outlined in Supplementary Figure 1. Rows indicate the observed classification of players into their correct AFL participation pathway levels. Columns show the predicted classification of players based on their physical fitness attributes and movement ability characteristics.

Figure 1. Schematic diagram of the AFL participation pathway outlining the competition hierarchy and flow of players within the local participation and talent pathway levels. U: Under

Figure 2. Distribution of physical fitness attributes of players within each AFL participation pathway levels included in the classification-tree model. U: Under

Figure 3. Distribution of movement ability characteristics of players within each AFL participation pathway level included in the classification-tree model. U: Under

Figure 4. Multivariate analysis of variance (MANOVA) between AFL participation levels, physical fitness and movement ability tests. Values are presented as the effect size (ES) between levels, with * denoting a significant difference ($p \leq 0.005$) between levels. MSFT: Multi-Stage Fitness Test, RDL: Romanian Deadlift, U: Under, VJ: Vertical Jump

Supplementary Figure 1. Classification-tree illustrating the percentage of players classified into AFL participation pathway levels based on physical fitness tests and movement ability parameters detailed above each node. Note, n = number of players classified at each level within each node. RVJR: Running Vertical Jump (Right Leg), U: Under

Figure 1

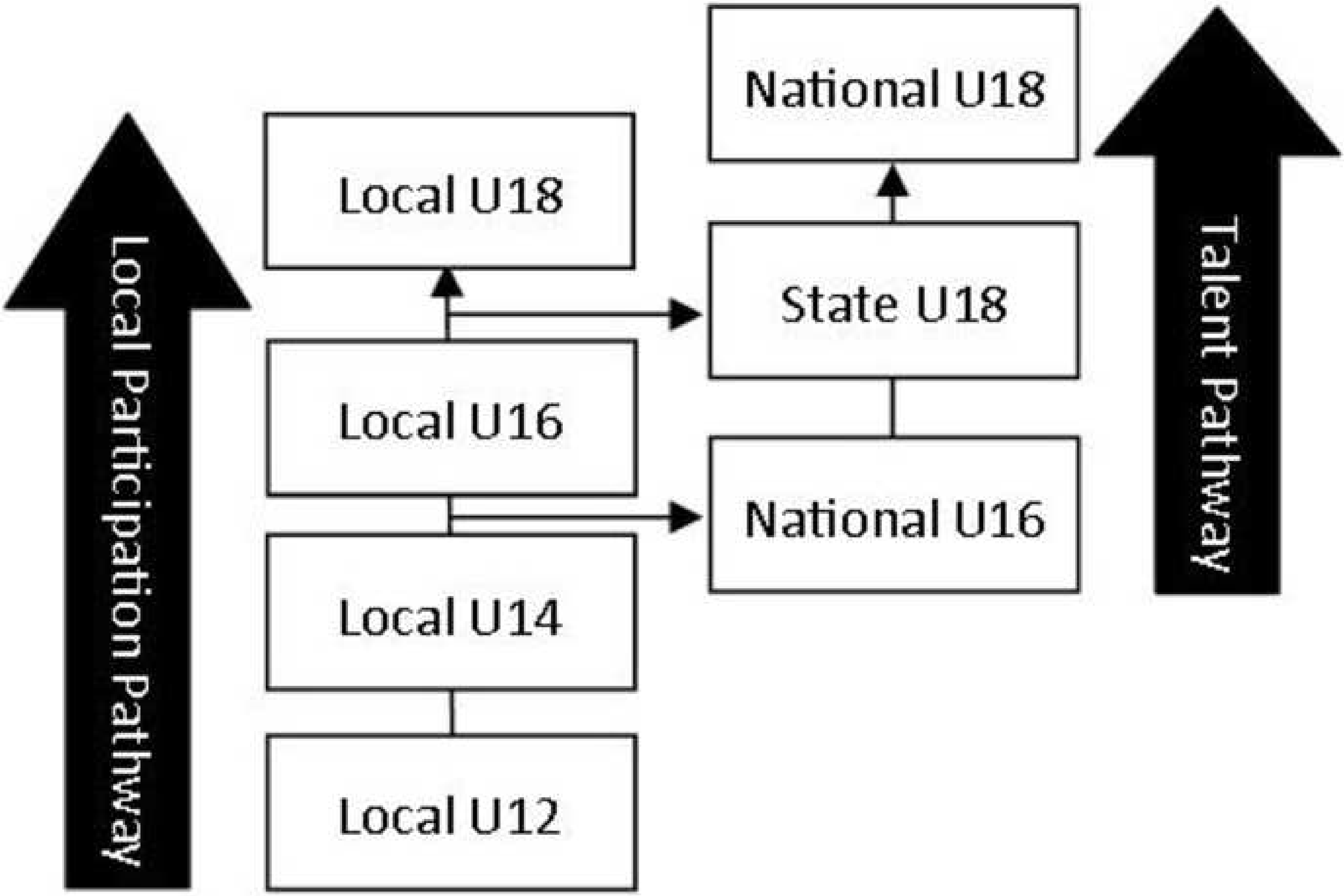

National U18
Local U18
State U18
Local U16
National U16
Local U14
Local U12
Local Participation Pathway
Talent Pathway

Figure 2

Click here to access/download;Figure;Fig 2.tiff

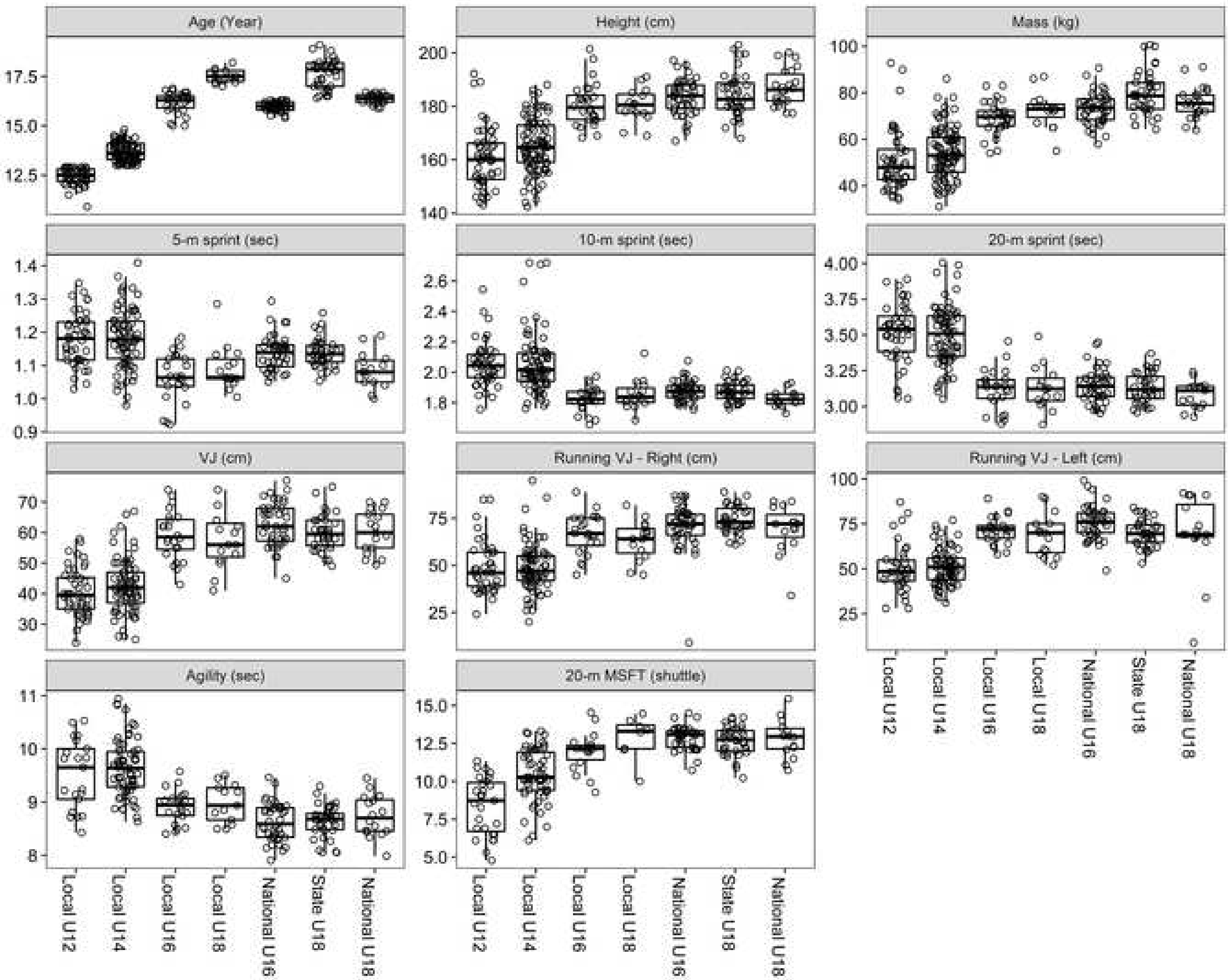


Figure 3

Click here to access/download;Figure;Fig 3.tiff

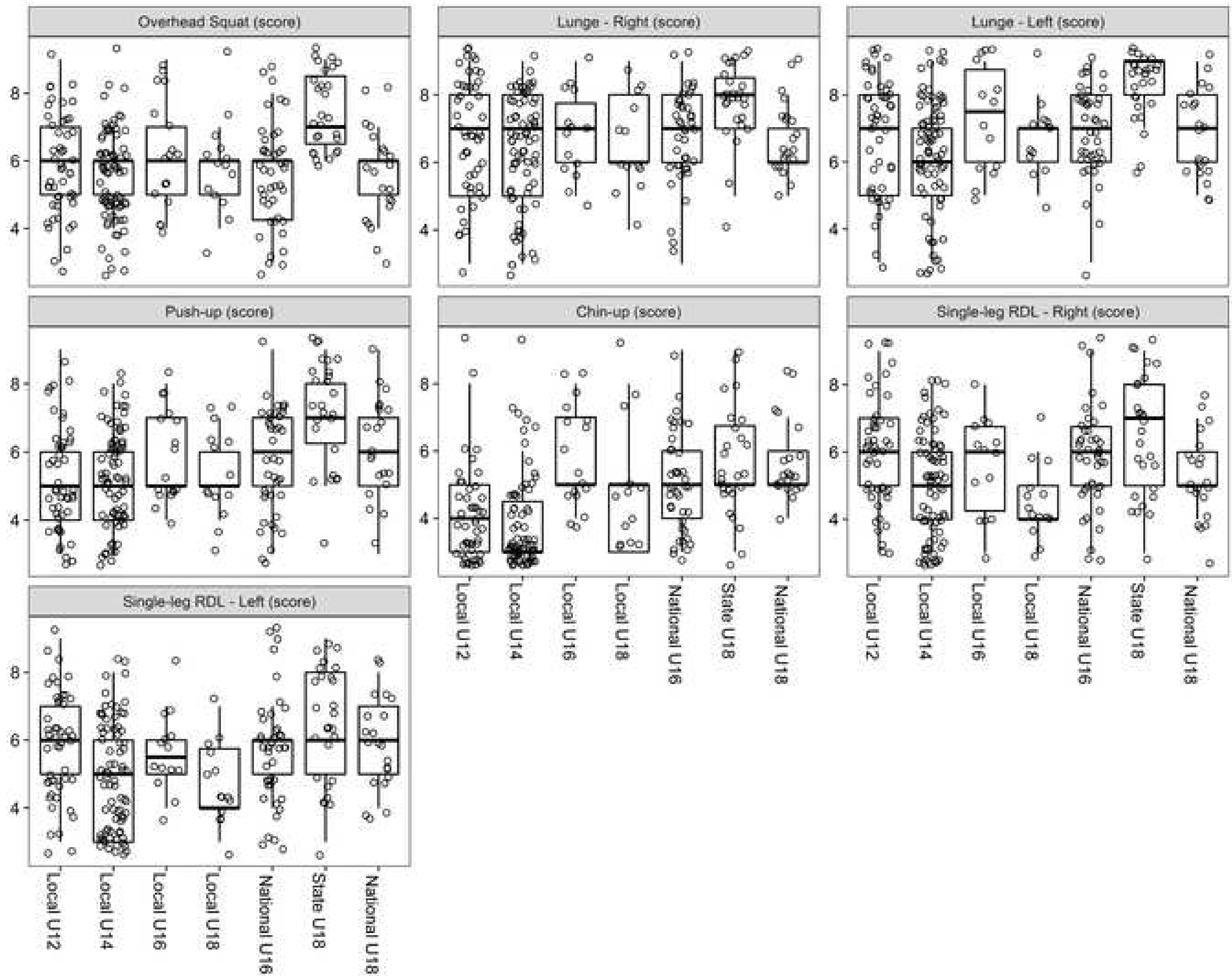
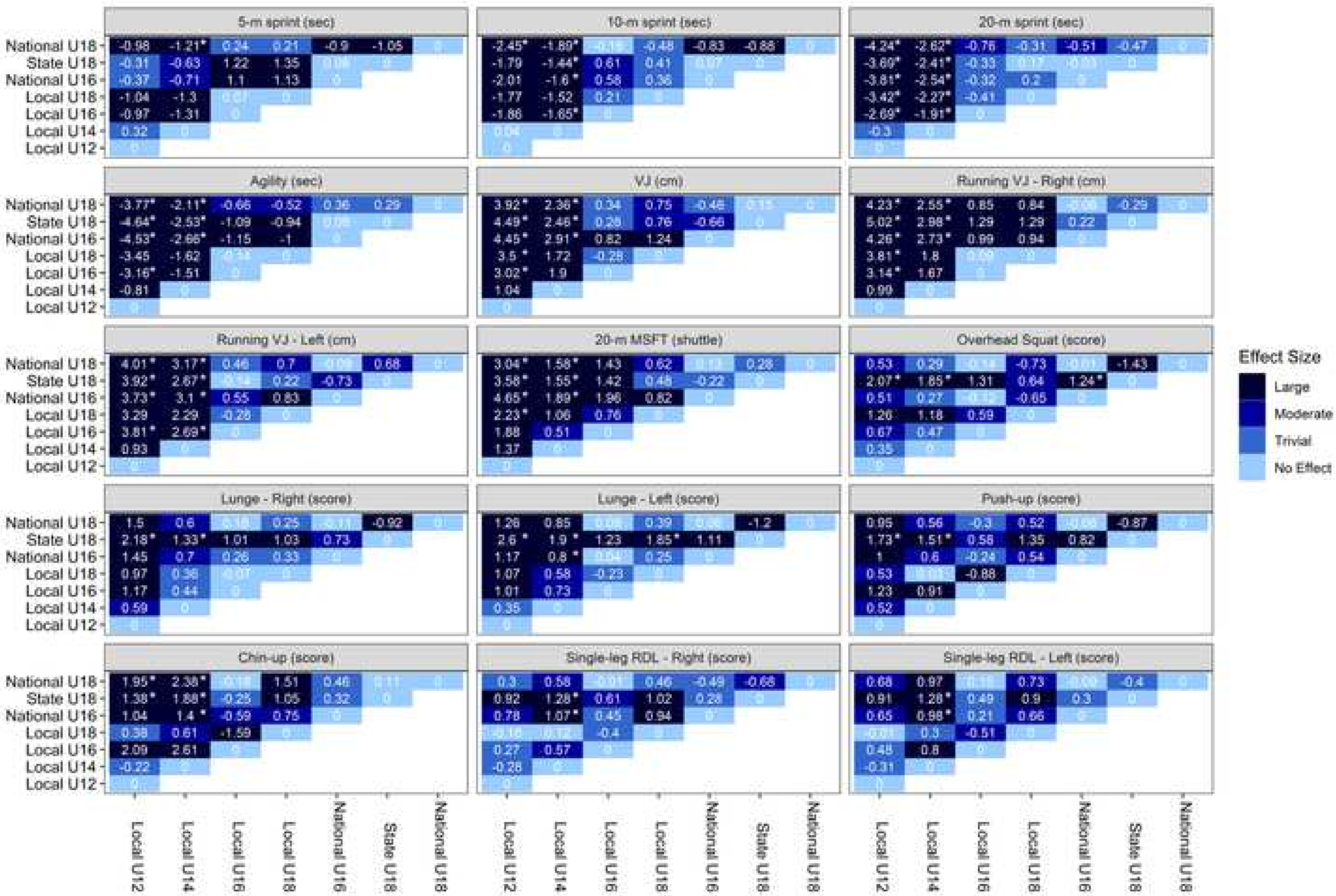


Figure 4

Click here to access/download;Figure;Fig 4.tif



Supplementary Figure 1

Click here to access/download;Figure;Supplementary Fig 1.tif

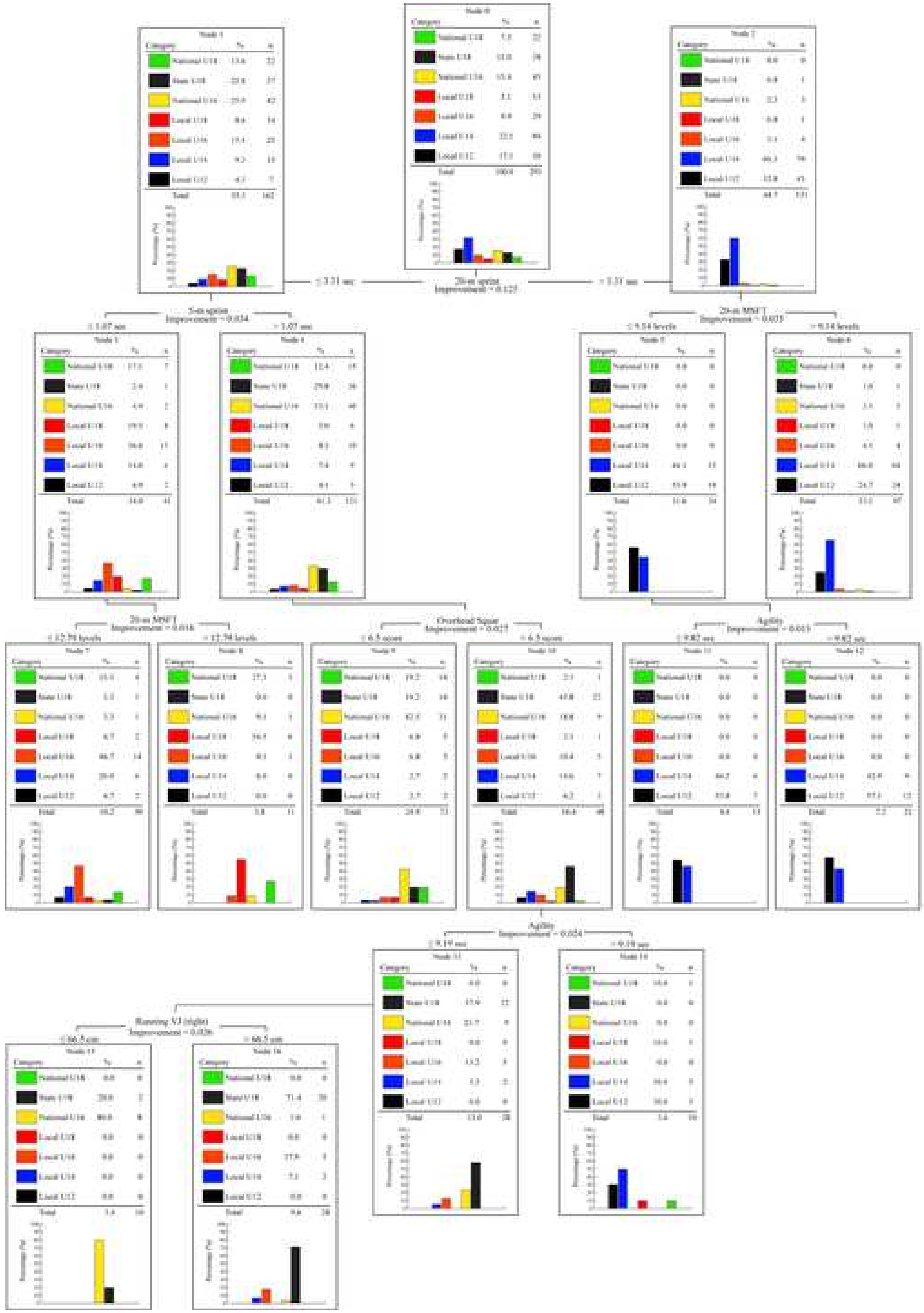


Table 1

Table 1. Confusion matrix for the classification tree model outlined in Supplementary Figure 1. Rows indicate the observed classification of players into their correct AFL participation pathway levels. Columns are show the predicted classification of players based on their physical fitness attributes and movement ability characteristics.

Observed	Local U12	Local U14	Local U16	Local U18	National U16	State U18	National U18	Classification Rate
Local U12	19	27	2	0	2	0	0	**38%**
Local U14	15	69	6	0	2	2	0	**73%**
Local U16	0	4	14	1	5	5	0	**48%**
Local U18	0	2	2	6	5	0	0	**40%**
National U16	0	3	1	1	39	1	0	**87%**
State U18	0	1	1	0	16	20	0	**53%**
National U18	0	1	4	3	14	0	0	**0.0%**
Overall Percentage	**12%**	**37%**	**10%**	**4%**	**28%**	**10%**	**0.0%**	**57%**